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COMPUTER ASSISTED TRANSLATION OF BRAILLE MUSIC

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INTRODUCTION

The Problem

The number of Braille stereograph operators having a knowledge of music is declining. Facing the possibility of a cessation in production of press Braille music, the American Printing House for the Blind (APH) proposed the development of a system of computer assisted Braille music production.

Work on this project was begun on May 10, 1971 under a grant administered by the Library of Congress, Division for the Blind and Physically Handicapped. The objective of the project is to continue the production of Braille music at APH. The goal for the first year was to bring the system to the point of development such that some music titles would have been embossed.

Resources

The resources available at APH for this project include:

1) an IBM 7040 computer for the production of Braille;
2) a working system for computer translation to Grade 2 literary Braille;
3) automatic plate making equipment;
4) many years experience in all phases of the production of press Braille.

Personnel

APH personnel working directly on this project are William Watkins, music specialist, and John Siems, computer programmer. In addition, available for consultation are Robert Haynes, manager APH data processing department, and Mrs. Nelle Edwards, APH Braille music transcriber and authority.

INITIAL RESEARCH

Music Engraving

Traditional methods of preparing music for publication include those of engraving and, to a much lesser extent, autography. Strictly speaking, the term "music engraving" refers to the process of hammering impressions into metal plates with sets of steel punches, although the term now generally refers to whatever process is used to prepare music masters for offset printing. Autography refers to the pen and ink method of "drawing" music with rulers, templates, etc., the results of which can then be photographed for printing.

Some fourteen music publishers were contacted in order to determine to what extent automation is now being employed in the production of ink-print music. Approximately a half-dozen replies were received.

We were informed that traditional engraving via punches and metal plates is a dying profession--a situation which closely parallels the decline in numbers of Braille music transcribers. Likewise, few autographers remain. Although there are various new methods of preparing music for printing, the most common modern method is with the use of music typewriters. As a result of our inquiries, we were informed that various attempts have been made to involve computers in the production of ink-print music.

We were already aware of Stefan Bauer-Mengelberg's project to prepare music via the Photon printer. This project was begun around the beginning of the 1960's but to date has not been completed.

Ted Ross, manager of Hansen Press' music engraving department and author of a new book on the subject, informed of the efforts of Lejaren Hiller toward computerized music printing. During the late 1950's, Dr. Hiller, in association with R. A. Baker, Cecil Effinger, and Robert Oliver, adapted a music typewriter as a computer input-output device for a project at the University of Illinois. Dr. Hiller was telephoned and our projects were discussed at some length.

Mr. Ross also supplied the name of Armando Dal Molin, a

music engraver on Long Island who is engraving music via computer.

Also among the responses to our inquires was included a letter from Mr. Daniel Gendason, Executive Vice-President of Belwin-Mills music publishers, which led to a conference with Mr. Gendason at a later date.

Music Scholarship

In the academic world, particularly in the field of musicology, there is an increasing use of computers as an aid in research and analysis. Most of this work has been documented in journals, and several books on the subject have been published. Considerable time has been spent in research at university libraries, and a number of scholars were contacted.

Interviews

During the week of July 19, a trip was made by APH representatives to the New York City area for the purpose of conferring with music scholars, publishers, and engravers. Of particular interest were those who were working on computer-music projects.

A visit was made to Armando Dal Molin, President of Music Reprographics, Ltd. in Oyster Bay, N. Y., who engraves music via a computer notesetting process. As input, he has adapted a Friden Flexowriter into a music typewriter which produces a typed page of music and also punches this information into a computer-readable tape. He offered to custom build one of these machines for purchase by APH. After computer processing, the final operation of his system is the actual engraving of music via the Photon printer. The Photon contains a character set of 800-900 symbols, 200 of which are music characters specially designed by Mr. Dal Molin.

A visit was made to the offices of Belwin-Mills music publishers for a conference with Mr. Daniel Gendason. He informed of some computer use in one of their own engraving shops and telephoned the shop manager, Robert Girlamo. Revealed was that the computer is used to indicate the punctuation (spacing) of the music characters and the actual notesetting is done via music typewriters.

A visit was made to the office of Barry S. Brook at the City University of New York. Mr. Brook was kind enough to provide a copy of a new book under his editorship which contains numerous articles on computer-music projects and rather complete outlines of certain music input languages.

Raymond Erickson of Queens College was contacted concerning

his work in finalizing Stefan Bauer-Mengelberg's DARMS input language. He indicated that with Mr. Bauer-Mengelberg's permission, he would provide APH with an outline.

Study of Braille Music Notation

One of our major tasks is the study of Braille music notation. Considerable time will continue to be spent on this element of the project. Toward that end, the personnel for this project were privileged to attend meetings of the Advisory Committee on Braille Music of the Braille Authority which were held at APH during March and May of 1971. Many of the problems of Braille music notation were discussed and various solutions were proposed.

SYSTEMS DESIGN

A Survey of Input Methods

Keypunch Methods

With a few notable exceptions, most music entered into computers is being done by music scholars for the purposes of research and analysis. The most widely used input machine is the keypunch, for which several languages have been written. With few exceptions, these languages have been published and have been studied in considerable detail by APH.

Music Typewriters

Mentioned were the efforts of Lejaren Hiller, et al., in a music printing project at the University of Illinois which utilized a music typewriter as an input-output device. Referred to also was Armando Dal Molin's Photon engraving process which makes use of music typewriter input machines.

Cathode Ray Tube (CRT)

Programs that accept and play back two-dimensional music notation have been developed by W. B. Barker and Don Cantor for a PDP-1 computer with display oscilloscopes at Harvard University. Graphics are displayed on the faces of CRT units.

Optical Character Recognition (OCR)

References to the proposed use of OCR devices are encountered frequently in our research. Notable are references to the work of David Prerau at MIT which mention his use of OCR in reading transparencies made from short segments of Mozart duets.

Selection of an Input Method

From the standpoint of APH's needs, and taking into account the types and particularly the quantity of music we anticipate

having to accommodate, a review of the various input methods was made.

Keypunch Languages

Use of a keypunch language for music input incorporates the advantage of the utilization of existing equipment. Futhermore, this machine can, of course, be used for other applications when not being used to encode music data. An inherent disadvantage is its limitation to a one-dimensional format.

Traditional music notation is two-dimensional (i.e., consecutive events are placed horizontally and simultaneities, as well as pitch, are indicated by their vertical position). Use of a keypunch language necessitates the reduction of music notation to a one-dimensional, horizontal-only representation. In addition, rather than music symbols, only alphabetic, numeric, and punctuation characters can be used, thus rendering a representation twice-removed from the original notation.

Don Cantor, in an article describing a computer-music project at Harvard University, states that, "Efforts to put a large quantity of music into computer storage by encoding its two-dimensional notation with a one-dimensional sequence of letters, numbers, and punctuation marks have been hampered by persistent clerical errors: no such code has been found easy for a human to use." (Don Cantor, "A Computer Program that Accepts Common Musical Notation", Computers and the Humanities, VI/2, Nov. 1971, 103-9)

In describing a major computer-music project at Princeton University which utilized a keypunch language input, Lewis Lockwood relates that "The 22 complete Masses and separate movements (by Josquin Desprez) published in the Smijers edition cover some 600 printed pages of music, and the most optimistic estimate was that this would require some 800 hours of keypunching (not to mention proofreading) to be carried out by paid student keypunchers armed with patience, fortitude, and a modicum of musical literacy. Actually the laborious tasks of keypunching, even divided among many hands, have gone at an uneven pace, and we have learned valuable lessons about human frailty in discovering how difficult it is to achieve a letter-perfect representation of any body of music, free of errors large and small." (Lewis Lockwood, "A Stylistic Investigation of the Masses of Josquin Deprez. . .", Musicology and the Computer, Brook, ed., New York, N. Y., CUNY Press, 1970)

APH's experience with Braille music notation (also largely a horizontal notation) leads us to conclude that this procedure of reduction to a horizontal-only format with other than music characters is one of the more tedious aspects of this skill

which fewer people are becoming interested in acquiring. For these reasons, APH investigated other methods of input.

CRT

Don Cantor and W. B. Barker's remarkable work at Harvard University is, at present, largely a pioneer effort, being experimental in nature. In addition to having available at present only about 17 different symbols, Mr. Cantor states in the aforementioned article, "The program has some conspicuous limitations: beams are not available; only upward stems are used; an accidental must be repeated before each note it modifies; only the pitches from D-flat below the bass clef to B-sharp above the treble are available; only one ledger line is permitted between the staves." "A full display editor for music would take years to develop, with unforeseen difficulties along the way." Commenting on the financial aspects of such a project, he relates, "We ruefully acknowledge that the equipment a display editor uses is at present very expensive. Moreover, a scope, unlike a keypunch for cards or tape, requires the attention of a computer."

The thought of developing such a system at APH would far exceed the range of this project.

OCR

Any attempt toward computer involvement in a Braille music translation program must necessarily have to accommodate literary Braille translation. While vocal music with its literary text is the most conspicuous example of this requirement, even the simplest music usually contains tempo indications, dynamic marking, etc. A recent study conducted by APH tested optical scanning as a possible input method for our literary Braille program. The results indicated that OCR is at present more expensive and less accurate than keypunching. Compounding the problem with the addition of music characters in their two-dimensional array (and being unaware of any large-scale efforts having been attempted toward music scanning), APH's decision was to bypass OCR as a possible input method for this project.

Music Typewriters

Having decided against other methods of input, efforts were made to concentrate on the music typewriter method of converting music into machine-readable form. Among the factors considered was that the only system now in use to input large quantities of music (including a large repertory of music, alphabetic, and numeric symbols) is Armando Dal Molin's system at Music Reprographics. As noted, he modifies Friden typewriter-to-paper tape units to music typewriters and uses them to furnish the input for his Photon music engraving process.

After considerable correspondence and a visit to his plant, our conclusion was that in order to be compatible with APH's present data processing equipment, a machine supplied by him would have to include rather extensive modifications. Specifications for the proposed modifications were written and submitted to his firm.

A subsequent reply to APH tentatively indicated that not all of these modifications would be incorporated and that APH would necessarily have to acquire some additional data processing equipment should the decision be made to acquire this machine. Specifically, we would need eight-channel tape processing equipment. As a result, the decision was made to explore other possible sources.

On Sept. 28, APH representatives visited the IBM typewriter plant at Lexington, Ky. for a conference with some five of IBM's typewriter personnel. Our goal was to inquire as to whether IBM would be interested in assisting APH toward the development of a music typewriter encoding device. Although the results of the meeting indicated that IBM would not undertake the project, APH received some valuable information.

We were told of a past project of IBM in developing an electric music typewriter in association with Cecil Effinger. Dr. Effinger, with whom we already were corresponding, is now president of Music Print Corp. (MPC) which manufactures music typewriters, and is on the music faculty of Colorado University. With this new information concerning his experience with IBM, and considering his project with Lejaren Hiller for the University of Illinois, APH's representative visited Dr. Effinger for a conference concerning his possible assistance on this project. He indicated that he would be most willing to work in association with us in producing this machine and that he has encountered and solved similar technical problems in Dr. Hiller's and other projects.

Having been informed by IBM of a typewriter to keypunch machine, the model 826 under their manufacture, APH began corresponding with MPC toward the modification of the 826 to a music typewriter-to-card punch machine. A list of specifications was written and submitted to this firm.

Following a second conference with Dr. Effinger, an agreement was reached for the modification of an IBM 826 Typewriter Card Punch machine to APH's specifications.

The machine will consist of two basic units--a music typewriter (including music characters, alphabet, numerals, and punctuation characters) which will be cable-connected to a keypunch machine. In addition to typing a character, the depression of a typewriter key will also generate a card code in the keypunch

machine. The result will be two-fold; 1), a typed page of music (which can later be proofread for errors), and 2), cards containing corresponding data punched in standard alphameric keypunch characters.

In music notation not only are the characters themselves significant but of equal importance are their locations on the music staff. Therefore the cards will also contain punches which will correspond to the vertical locations (positions on the music staff) of the characters.

On the music typewriter, vertical placement will be achieved by operating a few keys which will rotate the carriage to the desired staff position. This will also generate unique card codes which will correspond to the degree of rotation. In addition, of course, other codes will be reserved to indicate spacing and backspacing.

Thus the two-dimensional aspects of the typed page of music will be registered as punches to indicate characters as well as their horizontal and vertical placement.

Processing

In the area of computer processing, there have been two emphases. An attempt has been made, on the one hand, through analysis of music and music Braille, to arrive at concepts which would form the basis for longer range developments in converting various types of music from inkprint to Braille. On the other hand, programs have been written for immediate use to implement some Braille music production.

Analysis

The study which has been made of the Braille music code indicates that the task of transcribing can be divided into several steps, each of which involves certain data transformations.

The first step is that of representing music as a set of distinct units. This step will be performed by copying inkprint music on the music typewriter input device. While it is anticipated that the typed page will closely resemble the original printed page, a data transformation of considerable significance will have occurred. Inkprint symbols of variable shape and spacing will be represented by symbols made up of one or more typed characters having specific vertical and horizontal locations. As a result, the music text will consist of an

aggregation of units, each unit being an identifiable character in an identifiable position.

The second step is a reconstruction of the music text. Some units may be grouped together into larger units. For example, a solid note head adjacent to a stem, which in turn is adjacent to a flag, may be identified as an eighth note. Or, a series of adjacent letters in a horizontal line may be identified as a word. Other units may be interpreted singly, but on the basis of relative location. A dot vertically aligned with a note may be recognized as indicating a staccato, while a dot following a note may indicate duration. A numeral located on a certain staff line and directly above another numeral may be interpreted as specifying the number of beats per measure. Whereas the first step is an analysis of music for processing, the second step is a synthesis in which relative distance and direction are used to determine meaning.

The third step in transcribing is an editing procedure. Information which will be required in later processing will be filled into the music text. In some cases data may be added to make explicit that which is implicit in the music characters. Examples of this type of data are: time elapsed in a measure at a certain point; accidentals in force at a given time; and the count of a succession of marks, such as accents. Another part of editing might be the insertion of division symbols. These would specify the boundaries of such divisions as measures and beats. Editing will also, no doubt, include the handling of special format and control symbols which have been entered as part of the input. The purpose of this step is to make accessible those features of music having particular significance for Braille encoding.

A fourth step takes into account the structure of Braille as primarily a horizontal language. Braille music transcription requires rearrangement of the data from the two-dimensional notation of inkprint into a succession of symbols. This means that each text item must be classified, evaluated, and assigned a priority. The items can then be placed in order for appropriate Braille representation.

The fifth step completes the transcribing procedure. Braille text is produced by replacing the symbols of the edited music text with Braille signs. There are many cases in which the series of signs used to represent a given group of music symbols varies with the potential position of the signs on the Braille line. Making decisions in these situations will be a part of this step. Also, in this step an integration of the music code with the literary Braille code must be achieved. All published music contains literary material to a greater or lesser degree. Completing the transcription requires interaction with literary translation.

Programming

While work was being done toward an analysis of Braille music as a basis for a general approach to transcribing, an effort was also being made to develop and to put into operation the initial versions of computer programs. The purpose was to begin limited computer-assisted production and, through experience in using the Braille code, to complement information available in the manuals. Programming support in the first year was in two versions.

First Version

In the beginning of program development, one of the important considerations was the presence of literary material in music text. A music publication contains not only music symbols but also titles, word expressions, and footnotes. Any program for actual use, must accommodate the code for literary Braille.

Another primary consideration was the likelihood that in any computer system for Braille music processing, even as the system became more advanced, there would need to be a facility for entering literal Braille data. Experience in translating a variety of materials into Grade 2 Braille had shown that in certain unusual instances it is advantageous to be able to specify a particular Braille sign. It seemed that this might be even more true in music.

It was decided to start with the development of the facility for handling Braille literals--a capability which would be of diminishing but of continuing usefulness. To provide this facility and also to provide for handling literary content, a system was designed for processing music mnemonics. A list of about 350 names for Braille music signs was developed. These names were made up of the 47 letters, numbers, and punctuation signs used by the IBM 026 keypunch. Input for the system consisted of this set of mnemonics plus literary words or phrases. Input also includes two special symbols to indicate the beginning and end of a word or word series to avoid possible confusion between words and alphabetic names of music symbols.

A Braille mnemonics program was written which would accept this input. The program identifies the symbol names and converts them to the appropriate Braille characters or series of characters. Characters are specified by means of the Braille sign numbers. This data along with the literary data is written in a format which can be used as input to the Grade 2 Braille translation program in operation at APH.

The Braille translation program completes conversion into Braille data. A non-literary feature of the translation program permits processing of the signs for Braille music generated by

the mnemonics program. Literary text is translated in the usual way. From the translation operation it is possible to obtain printed listings or punched cards to operate an embossing machine.

Second Version

In moving to the next version of programming support, primary stress continued to be placed upon the occurrence of words and phrases in music text and the handling of Braille literals. In addition to these two factors, a further factor considered was the progress which had been made in determining a method of input. It appeared that programs for present use should, where possible, be pointed toward the music typewriter device to be employed in the future.

In regard to input, thought had also been given to an alternate to the special typewriter. It seemed possible that for some types of music there could be a keypunch language which would simulate typewriter action. This language might be used in case of a work overload or at times when the principal input device was being repaired. Programming development could appropriately be in terms of this projected language.

A final factor influencing the next level of programming was the goal of processing some of the many Braille music signs whose usage is conditioned by location on the Braille line. With the proper program routines, conditional signs could be included in the input and the final decision regarding their use made by the computer.

Keypunch to 826. - The second version system consisted of four programs corresponding to successive phases of processing. The first program reads keypunched input data. Data is in the projected format of the alternate keypunch language. Three modes are projected: literary text, Braille mnemonics, and symbols for inkprint music signs. The system implements the first two of these modes. Special symbols mark the opening and closing of extended literary text. Mnemonic terms are used for music. Word expressions may be inserted within the Braille mnemonics mode. The set of sign names used in the first version was refined and expanded. Additional names were developed for signs to be brailled conditionally under program control.

The output of the program is a series of records having the same data structure as the cards which will be punched by the modified IBM 826--the typewriter input device. This format contains 39 data characters plus two shift characters making it possible to represent 78 typed graphics. Additional characters indicate forward and backward spacing and vertical spacing. This program has the effect of simulating the future music input

device by producing the same type of output which will be produced by that unit.

826 to Array. - The next program interprets the 826 type of output data. This means that there are two entry points to the system. Data may be entered by keypunch and processed by the first program, or data may, in the future, be entered on the music typewriter resulting in punched cards. In either case data is ready for the second program which provides the next step in the system.

On the basis of character and space interval information which has been recorded, the characters are assembled and placed in a two-dimensional array. Because of horizontal and vertical spacing action, characters which are clustered in music notation may be scattered in the 826 records. Record position reflects the sequence in which typewriter keys are depressed, not the printing point of the character. From the content of the records the program constructs in the computer an image which corresponds to the typed page.

The fact that key strokes are recorded successively permits identification of multiple characters typed in the same position. When, in setting up the array, two characters are found to have the same vertical and horizontal alignment, the program may replace the combination with another character. The use of superimposed graphics expands the music character set beyond the 78 individual typewriter graphics.

Each item in the array can be described as a character with a horizontal and a vertical location. The program takes this information from the array and writes as output a series of characters and their coordinates.

Array to Numbered Signs. - The third program scans the characters from the 826 to Array program and performs a grouping on the basis of the coordinate information. Groups are identified as words to be translated or mnemonics to be interpreted. Mnemonics are converted to series of signs with each sign being given an identifying number. An output is developed made up of words of literary text and numbers which represent the music text.

Numbered Signs to Braille. - Conversion to Braille in the second version is accomplished by a program which runs parallel with the Grade 2 Braille translation program. As data which has been generated by the third program is read, the numbered signs are indentified and associated with the correct Braille dot configuration. The conditional signs are then further examined for their potential position with reference to the beginning or end of a Braille line and with reference to other data on the line. On this basis characters may be added or deleted. The

music hyphen, octave marks, and slurs are among the conditional signs.

Literary material is translated by the Grade 2 program. This permits handling of title information, running page headings, and editorial notes. The translation program and the fourth program of the system for music processing interact, the latter handling the music signs. The final Braille data is the result of this interaction.

The four computer programs, "Keypunch to 826", "826 to Array", "Array to Numbered Signs", and "Numbered Signs to Braille", have been used in some production. The language in which the programs are written consists of assembler instructions and also higher level instructions. Included in the second category are instructions which facilitate character handling. The programs run on the IBM 7040 Data Processing System in operation at APH.

Output

The output method for computer-translated Braille books and magazines is suitable for Braille music. Cards are punched by the computer which contain the Braille text and control characters for the format of the Braille page. The cards are read by a card reader connected to an automatic stereograph machine.

The automatic stereograph machine, which is manufactured at APH, embosses folded metal plates on both sides. Attention required by the machine is minimal so that one person can operate several machines at the same time. After the plates are embossed, they are placed on a press and are used to produce the interpoint pages of a Braille volume.

RESULTS AND CONCLUSIONS

Production

While a survey of larger proportions was beyond the scope of this project, local educators were interviewed in an attempt to select music titles which are currently being used by teachers. A resulting list of titles was obtained; in collaboration with L. C., the following were selected as the first titles to be brailled with computer assistance:

- "Advanced Studies for the Clarinet", by Victor Polatschek (published by G. Schirmer)
- "18 Exercises for Flute", by T. Berbeguier (published by G. Schirmer)
- "40 Studies for Clarinet", by C. Rose (published by Carl Fisher)

Due primarily to the fact that our music typewriter input system was not yet operational, input was via keypunch machine using a language written at APH for this phase of the project. The three titles were embossed into plates and will appear in upcoming APH Braille music catalogs.

Braille Methodology

As has often been noted, there exists the problem in Braille music of there being more than one accepted method of notating a given music example. On many points the authorities disagree; there is no consensus on a number of issues.

The first volume we produced ("Advanced Studies for the Clarinet", by Victor Polatschek) is a case in point. This volume, some 73 pages, was submitted twice for proofreading to different authorities. Excluding surface errors (definite errors such as omissions, incorrect symbols, etc.), the first authority suggested several changes in format. The volume was altered accordingly before being submitted to the second reader.

The second reading was then compared with the original and the first proofread versions with the result that numerous suggested changes in format and basic procedural methods were noted. No attempt is made here to make an evaluation except to note that nearly all of the differing methods of procedure can be

verified by various authoritative sources as being acceptable ways of notating music in Braille.

Thus, we conclude that this problem of disagreement among the authorities is more acute than we originally supposed. It could well be that an attempt to achieve extensive standardization of Braille music notation is beyond the scope of this project. Indeed, it could develop that standardization would be a separate project in itself which, even if possible to complete, could take several years.

Utilizing an approach we do not prefer, we suspect that the only method at our disposal in order to achieve production may involve, on our part, some arbitrary selection among various approved procedures.

Input Methods

Having produced three volumes of Braille music via the keypunch method of music input, we conclude that; 1) the desirable step toward freeing the braillist from the Braille writer was achieved; and 2), although the system could be improved by futher development, the number of errors occasioned by the use of this input method is unacceptably high for a production schedule and the detection of such errors is cumbersome. Albeit as an initial effort, use of the keypunch machine enabled us to produce some music the first year, this experience tends to reaffirm our decision to concentrate on the development of a two-dimensional encoding device.

Programming

Results from programming in the first year were that it was possible to use the computer in putting music into Braille and that some experience was acquired in the task of transcribing. Techniques were worked out which will be useful in future developments.

The function of music braillist was changed from that of making trial transcriptions on a Braille writer to working at a desk using symbolic music abbreviations and at least partly freed from attention to Braille line division. Printed dot listings are made by the computer as a means for checking work which has been done. Revisions are accomplished relatively easily before the final output. Also, with the computer system, knowledge of Grade 2 Braille is not required.

PROJECTIONS

Personnel Requirements

As our literary translation program requires the assistance of personnel who know the Braille language, possibly to an even greater extent so will our music translation program. Being even more complex and less standardized than literary Braille, the music program will necessitate the services of a consultant to make editorial decisions.

Operators for our input machine system will be required to have some musical knowledge, much the same way as our keypunch operators are required to know the alphabet.

Processing Requirements

Initial programming efforts indicate that music processing requires considerable computer capacity--more than is required for translating inkprint to Grade 2 Braille. There are several reasons for this. One reason is the complexity of the music code. Another is the large amount of data which must be available in the computer for making certain decisions. Inkprint music notation is a very concise language and the content of even one measure of music in any other transformation can be quite bulky. Finally, music processing, at least in the final stages, involves not only conversion of music data to Braille but literary translation in addition.

A further conclusion from programming and analysis is that computer assistance for music transcription will probably consist of more than one program. Although the exact number of programs and the steps to be assigned to each is not certain at this point, it seems unlikely that all of the steps could be incorporated into one program to be run on a medium-size computer. Consideration of the different types of music increases the probability that for processing more than a single program may be employed.

Project Span

An attempt has been made to categorize various types of music into general levels of difficulty from the standpoint of computer processing. A tentative hierarchy of complexity is shown below on an ascending scale. The types of music we

consider most readily accessible to computer production are given first and ascend to the types of productions which we feel will take longer to achieve.

Level 1
One instrument, single staff, monophonic (a trumpet method book, for example).

Level 2
Two instruments, single staff, homophonic or polyphonic (ex.-- orchestral part-- two bassoons written on one staff). One instrument, single staff, polyphonic or homophonic ex.-- part for violin including double stops, polyphonic lines, etc.).

Level 3
Full score of single staff parts. Band parts including full score. Chamber music (ex.-- string quartet, parts and score).

Level 4
Notation utilizing multiple, interdependent staves (ex.-- keyboard music).

Level 5
Full score including multiple staff parts (ex.-- orchestral score including harp and piano). Solo part with piano accompaniment.

Level 6
Vocal music, vocal scores with keyboard accompaniment, full orchestral score including chorus.

Level 7
Condensed score, condensed conductor's part, piano-conductor score.

Our projection is that by the end of the second year, we will be in routine production of music of the second or third level of difficulty and will have produced, at least experimentally, some music of higher complexity. Although we envision this project as requiring a minimum of three years, we do not feel that an accurate prediction beyond the second year can be made at this time.

We have, at various times, attempted to compare this project to the time required to complete the first literary translation program by IBM. This is difficult to do because we have no way of knowing how many man-hours were spent during the approximate five year interim period between the initiation and completion of that project.

We definitely feel that the music program will be much more complex than the literary translation program. Moreover, as

already noted, it will be inclusive of our current literary program.

Reflections

Despite the problems outlined, we remain most optimistic about the possibilities of the success of this effort provided we are given enough time to complete this highly complex project. We see this approach as the best and perhaps the only solution to the very real possibility of the gradual extinction of press Braille music.